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formity at its base and the bearing on the general problem of the enormous scale of the batholithic granitic intrusions of late Animikie time.

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## DISCUSSION OF CORRELATION

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C. K. LEITH AND R. C. ALLEN

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### INTRODUCTORY STATEMENT

The non-productive eastern end of the Gogebic Range is folded, faulted, and associated both with intrusive and extrusive rocks. In the lack of sufficient exposures and exploration scarcely more than lithologic mapping was possible when the range was worked over by Irving and Van Hise.<sup>1</sup> Structural mapping was not attempted. In recent years, exploration of this area by drilling has connected some of the isolated outcrops of iron-formation bands and has made it possible to map the area structurally. This has been done effectively by Messrs. Allen and Barrett, who outline their results in the preceding paper. While there are still some parts of the area to which the structure and areal connections are obscure, certain features of exceptional interest from the standpoint of general Lake Superior geology have already been worked out. These are: (1) discovery of the fact that there is an intrusive granite with important metamorphic effects in the supposed eastward continuation of the Gogebic iron formation (Animikie); and (2) the existence of a ferruginous graywacke formation with jasper and chert bands, called the Copps formation, separated from the inferior Animikie series by a great structural unconformity and unconformably below the Keweenawan.

These facts raise interesting questions as to revision of the pre-Cambrian correlation of Michigan, which touch more or less also the correlations of the Lake Superior region as a whole. Leith thinks it possible that the Copps series may be of only local significance and require no general change, but he agrees with Allen that Michigan correlation should be carefully tested to ascertain whether the known facts can be better expressed by a different

<sup>1</sup> *Monograph 19, U.S. Geol. Survey, 1892.*

correlation than that heretofore used. Two main possibilities present themselves: (1) that the Copps represents a fourth Huronian series between the Animikie and Keweenawan; (2) that there are three Huronian series, and that the Copps formation may be equivalent to certain series elsewhere in Michigan, now otherwise correlated.

I. CORRELATION ON THE ASSUMPTION THAT THE COPPS FORMATION REPRESENTS A FOURTH HURONIAN SERIES BETWEEN THE ANIMIKIE AND KEWEENAWAN

If the Copps series be regarded as the remnant of a much larger series that has everywhere else been removed by erosion, it may be necessary to give it a position of the same general order as that of the Animikie or Upper Huronian, with the result that the Huronian series of Lake Superior become relatively lowered throughout the column, which would involve some changes in names. There would then be four Huronian series instead of three. The evidence, as it is, seems to afford too slight a basis for moving downward all the rest of the formations and introducing sweeping changes in nomenclature. The names now used have come to have well-understood significance, and well express the principal similarities and relationships of the pre-Cambrian series. When the extent and relationships of the Copps series can be more fully demonstrated it may be desirable to introduce such sweeping changes. To do so now would be premature and would almost inevitably require further changes when the significance of the Copps formation becomes more fully understood.

2. CORRELATION ON THE ASSUMPTION THAT THERE ARE THREE HURONIAN SERIES AND THAT THE COPPS FORMATION MAY BE EQUIVALENT TO CERTAIN SERIES NOW OTHERWISE CORRELATED

Allen and Barrett regard the Copps formation as the equivalent of the Upper Marquette series, the Princeton series,<sup>1</sup> and certain formations in other districts above the Animikie which are believed to be, as in the Gogebic district, below the Keweenawan. Leith

<sup>1</sup> R. C. Allen, "Correlation and Structure of the Pre-Cambrian Formations of the Gwinn Iron-bearing District of Michigan," *Jour. Geol.*, XXII (1914), 560-73.

believes that the evidence thus far available, while suggestive, does not constitute a sufficient basis for throwing over the present correlation, which brings out the main features of succession in common in the different districts, and that a revision introduces difficulties in local correlation quite as great as any in the old correlation. In order to bring out clearly the possibilities in the situation, the two views are presented below respectively by R. C. Allen and C. K. Leith.

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A REVISION OF THE CORRELATION OF THE HURONIAN GROUP  
OF MICHIGAN AND THE LAKE SUPERIOR REGION

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R. C. ALLEN

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The Huronian group comprises at least three unconformable series of pre-Cambrian sedimentary and associated igneous rocks separated from the younger Keweenawan series by a great unconformity and from the older Archean system by another more profound unconformity. The position of the group has been defined by the United States Geological Survey and by a committee of Canadian and United States geologists<sup>1</sup> (1904) as follows:

Paleozoic		Unconformity
	Keweenawan	Unconformity
		Upper
		Unconformity
Algonkian	Huronian	Middle
		Unconformity
		Lower
		Unconformity
	Keewatin	
Archean	Laurentian	Eruptive contact

Former correlations of the Huronian group as well as the entire pre-Cambrian of the various districts of the Lake Superior region in the United States are mainly the results of detailed field study and mapping by the United States Geological Survey. These

<sup>1</sup> *Jour. Geol.*, XIII (1905), 89-104.

studies have been published in a series of monographs on the most important districts and a final summary covering the entire region.<sup>1</sup>

In 1892 Irving and Van Hise published their completed work on the Gogebic iron range. They believed that the Huronian series in the Gogebic district comprises *two* unconformable series, the Upper and the Lower Huronian, and that the Upper Huronian or iron-bearing series is probably equivalent to the Animikie of the north shore of Lake Superior. In 1896 Van Hise, Bayley, and Smyth issued a monograph on the Marquette iron range. They found here *two* unconformable Huronian series, the *Upper* and the *Lower* Huronian, which were correlated with the *Upper* and the *Lower* Huronian of the Gogebic Range, the Negaunee iron-bearing series of the Marquette Range falling in the lower Huronian. These two works are the origin of the *dual classification* of the Huronian which was gradually extended to cover all of the other districts of the Lake Superior region until A. E. Seaman discovered, about 1902, that the "lower" Huronian of the Marquette Range is divisible by a great unconformity at the base of the Ajibik quartzite. In 1904 Seaman's discovery was formally recognized by an international committee of Canadian and United States geologists which adopted the tripartite classification of the Huronian group.<sup>2</sup> The Negaunee iron-bearing series was separated from the Lower Huronian to form the new Middle Huronian, but the old correlations outside the Marquette Range were preserved. In 1913 Allen accounted for a tripartite division of the Huronian in the Gwinn synclinorium and correlated the Gwinn iron-bearing series with the Negaunee

<sup>1</sup> R. D. Irving and C. R. Van Hise, "The Penoke Iron Bearing Series of Michigan and Wisconsin," *Monograph 19, U.S. Geol. Survey*, 1892; C. R. Van Hise and W. S. Bayley, "The Marquette Iron Bearing Series of Michigan, with a chapter on the Republic Trough, by H. L. Smyth," *Monograph 28, U.S. Geol. Survey*, 1896; C. R. Van Hise, J. M. Clements, W. S. Bayley, and H. L. Smyth, "The Crystal Falls Iron Bearing District of Michigan," *Monograph 36, U.S. Geol. Survey*, 1899; C. K. Leith, "The Mesabi Iron Bearing District of Minnesota," *Monograph 43, U.S. Geol. Survey*, 1903; J. M. Clements, "The Vermilion Iron Bearing District of Minnesota," *Monograph 45, U.S. Geol. Survey*, 1903; W. S. Bayley, "The Menominee Iron Bearing District of Michigan," *Monograph 46, U.S. Geol. Survey*, 1904; C. R. Van Hise and C. K. Leith, "Geology of the Lake Superior Region," *Monograph 52, U.S. Geol. Survey*, 1911.

<sup>2</sup> *Jour. Geol.*, XXII, No. 6 (1914).

iron-bearing series of the Marquette district. In 1914 Allen and Barrett found that the Upper Huronian, as described by Van Hise and Irving, on the east end of the Gogebic Range includes *two* unconformable series separated by a profound unconformity. This discovery has, in their judgment, opened the way for a revision of the correlation of the Huronian group of the Lake Superior region in which some of the difficulties and inconsistencies in the old classification largely disappear.

*The new correlation places the Animikie series in the Middle Huronian*, rather than in the Upper Huronian as in former correlations. Briefly stated, the steps in the argument are these:

1. The Animikie (iron-bearing) series of the Gogebic Range is the equivalent of the Negaunee (iron-bearing) series which constitutes the Middle Huronian of the Marquette Range; therefore, the Animikie series of the other Michigan districts, Minnesota, and the north shore of Lake Superior is also the equivalent of the Negaunee series, i.e., Middle Huronian.

2. The Negaunee series of the Marquette Range is unconformably overlain by the Upper Huronian. The Ironwood (Animikie) series of the Gogebic Range is also overlain unconformably by a series which is *unconformably beneath the Keewenawan*. This series is equivalent to the Upper Huronian of the Marquette Range. The Animikie is therefore Middle Huronian.

#### CORRELATION OF THE ANIMIKIE SERIES AS MIDDLE HURONIAN

*Correlation of the Ironwood series with the Negaunee series.*—The Ironwood (Animikie) iron-bearing series of the Gogebic Range is correlated with the Negaunee (Middle Huronian) iron-bearing series of the Marquette Range because (1) these series occupy identical positions in the Huronian succession of these districts, (2) are essentially similar, (3) are underlain and overlain by essentially similar series, (4) are in practically adjacent territory, and (5) there is substantial evidence of their equivalence through direct connection of the Negaunee series with the Vulcan (iron-bearing) series of the Crystal Falls–Iron River district which bears the same relation to a great granite batholith and its outliers as does the

Ironwood series of the Gogebic Range and its correlatives in the Marenisco and Turtle ranges.

The similarity of the successions in the Gogebic and Marquette districts is striking, and coupled with proximity would ordinarily determine a direct correlation of the similar series occupying identical positions in the group even were there no further evidence of identity.

### CORRELATION TABLE III

#### CORRELATION OF THE HURONIAN GROUP IN THE GOGEBIC AND MARQUETTE DISTRICTS

	Marquette District	Gogebic District
	Greenstone intrusives and extrusives	
	Clarksburg volcanics partly replacing Michigamme slate	Graywacke and slate
Upper Huronian	Michigamme slate carrying iron-bearing lenses (Bijiki schist)	Ferruginous and cherty slates and jasper
	Goodrich conglomerate— quartzite	Conglomerate
	Unconformity—	Unconformity—
	(Deep erosion)	Presque Isle granite Tyler slate
Middle Huronian (Animikie)	Negaunee (iron-bearing) for- mation and extrusive green- stone	Ironwood (iron-bearing) for- mation and extrusive green- stone
	Siamo slate	Palms quartzite and quartz slate
	Ajibik quartzite	
	Unconformity—	Unconformity—
	Wewe slate	(Deep erosion)
Lower Huronian	Kona dolomite	Bad River dolomite
	Mesnard quartzite	Sunday quartzite
	Unconformity—	Unconformity—
Archean		

The absence of slate above the Bad River dolomite should be considered with the evidence of deep erosion in Middle-Lower Huronian time in the Gogebic district which not only removed the slate if it was ever present there but also the entire Lower Huronian over the greater part of the range. In respect to the Middle

	MARQUETTE	GWINN	STURGEON	FELCH MOUNTAIN	CALUMET
Upper Huronian	<i>Greenstone intrusives and extrusives</i>				
	<i>Michigamme slate</i> partly replaced by <i>Clarksburg</i> <i>volcanics</i>	<i>Michigamme slate</i>		<i>Mica schist</i> <i>Ferruginous and mi- caceous quartzite</i>	
	<i>Bijiki schist</i> (iron- bearing)	<i>Goodrich graywacke and conglomerate</i>			
	<i>Goodrich quartzite</i>				
<hr/>					
Middle Huronian (Animikie)	<i>Negaunee iron for- mation</i>	<i>Slate</i> <i>Negaunee iron for- mation</i>	<i>Iron formation</i> ( <i>Negaunee</i> )	<i>Vulcan iron forma- tion</i>	<i>Hanbury slate</i> <i>Vulcan iron fo- mation</i>
	<i>Siamo slate</i> <i>Ajibik quartzite</i>	<i>Slate</i> <i>Arkose conglomer- ate</i>		<i>Felch schist</i>	<i>Felch schist</i>
<hr/>					
Lower Huronian	<i>Wewe slate</i>		<i>Randville dolomite</i>	<i>Randville dolomite</i>	<i>Randville dolo-</i>
	<i>Kona dolomite</i> <i>Mesnard quartzite</i>		<i>Sturgeon quartzite</i>	<i>Sturgeon quartzite</i>	<i>Sturgeon quar-</i>
<hr/>					
Laurentian					
Archean					
	Keewatin				

CORRELATION TABLE II

(Showing changes in Huronian correlation on the basis that the Animikie C

CALUMET	MENOMINEE	FLORENCE	CRYSTAL FALLS	IRON RIVER	VIEUX DESERT	CONOVER
		<i>Quartzite and con- glomerate</i>	<i>Michigamme slate</i>	<i>Michigamme slate</i>		
<i>Hanbury slate</i>	<i>Granite Quinnesec schist</i>	<i>Granite Quinnesec schist</i>	<i>Paint slate? Greenstone intrusives and extrusives</i>	<i>Paint slate? Greenstone intrusives and extrusives</i>	<i>Granite</i>	<i>G</i>
<i>an iron forma- tion schist</i>	<i>Hanbury slate Vulcan iron forma- tion</i>	<i>Hanbury slate Vulcan iron forma- tion</i>	<i>Hanbury slate Vulcan-Negaunee iron formation</i>	<i>Hanbury slate Vulcan iron forma- tion Slate</i>	<i>Slate and schist</i>	<i>K</i>
	<i>Quartzite</i>		<i>Ajibik quartzite Mansfield slate Hemlock volcanics</i>			<i>A</i>
<i>Randville dolomite Sturgeon quartzite</i>	<i>Quartzite Randville dolomite Sturgeon quartzite</i>			<i>Dolomite and quartzite (Saunders forma- tion)</i>		

Animikie Group is Middle Huronian)

ONOVER      MANITOWISH      TURTLE      MARENISCO      GOGEBIC      CUYUNA      MES

*Copps formation*

*Granite*

*Granite  
Greenstone intrusives  
and extrusives*

*Presque Isle  
granite*

*Presque Isle  
granite*

*Basic and acidic in-  
trusives and extru-  
sives*

*Embarrass  
granite(?)*

*Kyanitic, biotitic,  
garnetiferous, and  
graphitic schists*

*Slate*

*Greenstone extrusives  
and intrusives  
Slate*

*Tyler slate  
Greenstone extrusives  
Ironwood iron for-  
tion*

*Virginia (St. Louis)  
slate  
Deerwood iron for-  
mation*

*Acidic and  
intrusives  
Virginia sl  
Birwabik iron  
tion*

*Amphibole-magne-  
tite rocks*

*Iron formation  
Slate  
Quartzite*

*Iron formation  
Graywacke and  
quartzite*

*Palms formation*

*Slate  
Quartzite*

*Pokegama  
quartzite*

*Giants Rang  
granite*

*Dolomite*

*Dolomitic quartzite*

*Bad River  
limestone  
Sunday  
quartzite*

*Graywacke  
erate*

MESABI	VERMILION	GUNFLINT LAKE	ANIMIKIE
<hr/>			
<i>embarrass</i> <i>granite(?)</i> <i>acidic and basic in-</i> <i>trusives</i> <i>Virginia slate</i> <i>Wababik iron forma-</i> <i>tion</i>	<i>Rove slate</i> <i>Gunflint iron forma-</i> <i>tion</i>	<i>Rove slate</i> <i>Gunflint iron forma-</i> <i>tion</i>	<i>Black slate</i> <i>Iron formation</i>
<hr/>			
<i>Okogama</i> <i>quartzite</i>			
<i>Ants Range</i> <i>granite</i>	<i>Granite, dolorites,</i> <i>lcmporphyes in-</i> <i>trusive into rocks</i> <i>below</i>	<i>Greenstone and gran-</i> <i>ite intrusives</i>	<i>Granite and green-</i> <i>stone intrusive</i> <i>into rocks below</i>
<i>graywacke conglom-</i> <i>erate</i>	<i>Knife Lake slate</i>  <i>Agawa formation</i> <i>Ogishke conglomerate</i>	<i>Graywacke</i>	  <i>Slate, graywacke,</i> <i>and conglomerate</i>
<hr/>			

Huronian (Animikie) of these districts the situation is reversed, i.e., the thick Tyler slate formation above the Ironwood series is to be considered with the evidence of deep erosion of the Negaunee series and the development of iron ores on the exposed surface of the iron formation (now represented by the hard ores of the upper part of the Negaunee formation) prior to the deposition of the Upper Huronian. If the correlative of the Tyler slate was ever deposited on the Negaunee formation, it had been removed prior to the deposition of the Goodrich quartzite. The Middle Huronian (Animikie) of both districts is characterized by volcanic activity which continued on into and culminated in the Upper Huronian in the Marquette Range but terminated prior to the deposition of the Copps formation in the Gogebic Range.

There is a strong resemblance of the Copps formation of the Gogebic to the Upper Huronian of the Marquette Range in respect to lithology and order of succession. At the base of these series is a great conglomerate which is overlain by slate and graywacke. Neither series carries a great productive iron-bearing member, but both contain jasper and ferruginous beds near the base, which in the Marquette district are locally iron ore-bearing.

It can hardly be doubted that if Van Hise and Irving had discovered in 1892 the great unconformity at the base of the Copps formation on the Gogebic Range, and Van Hise and Bayley in 1896 the great unconformity at the base of the Ajibik quartzite on the Marquette Range, the correlation of the Huronian group of the Lake Superior region would have been *tripartite* from the beginning and not *dual*, for the correlations have been built up on these two type districts which were earliest studied by the United States Geological Survey. The Ironwood (middle) series would *then* have been correlated with the Negaunee (middle) series because, as above stated, they occupy identical positions in the Huronian succession, are essentially similar, are overlain and underlain by essentially similar series, and are in practically adjacent territory. The character of the reasoning which was

had been then available. There could *then* have been little if any reason for assigning these two iron-bearing series to different positions in the Huronian group and there is even less reason for such assignment today, because there is substantial evidence for the correlation of the Ironwood and the Negaunee series on other grounds, which will be discussed below.

CORRELATION OF THE VULCAN (IRON-BEARING) SERIES WITH THE  
NEGAUNEE (IRON-BEARING) SERIES

*Marquette and Crystal Falls districts.*—The basis of correlation of the formations of the Marquette and Crystal Falls districts is afforded by an indicated practical continuity of the Negaunee and Vulcan iron-bearing formations. In 1903 H. L. Smyth traced the Negaunee iron formation from the Republic trough southwest around two major anticlines to the northeast side of the great oval anticline in the northern part of the Crystal Falls district.<sup>1</sup> The relation of the Negaunee formation in this area to a persistent magnetic line may be seen on Fig. 3. From the vicinity of Michigamme Mountain, T. 44 N., R. 31 W., where the Negaunee formation is exposed, a magnetic line extends north through the Sholdice and Doan explorations, where the Negaunee is again exposed, and thence, north, northwest, west, and southwest around the great oval anticline into section 27, T. 46 N., R. 33 W., where it still coincides with the position of the iron formation. A short distance beyond the latter locality the line is broken, but it reappears after an interval of about 2 miles and passes through the Red Rock and Hemlock mines at Amasa and beyond, connecting with the iron formation which has been mapped as Vulcan or Upper Huronian.

The United States Geological Survey in 1911<sup>2</sup> accepted the conclusion that the magnetic line, exposures, explorations, and drift boulders prove the practical continuity of the Negaunee formation from Michigamme Mountain for a distance of 25 miles around the great anticline to a point about a mile south of section 27, T. 46 N., R. 33 W., but from a point about 2 miles farther on,

<sup>1</sup> See Smyth's discussion in *Monograph 36, U.S. Geol. Survey*, pp. 452-55.

<sup>2</sup> *Monograph 52.*

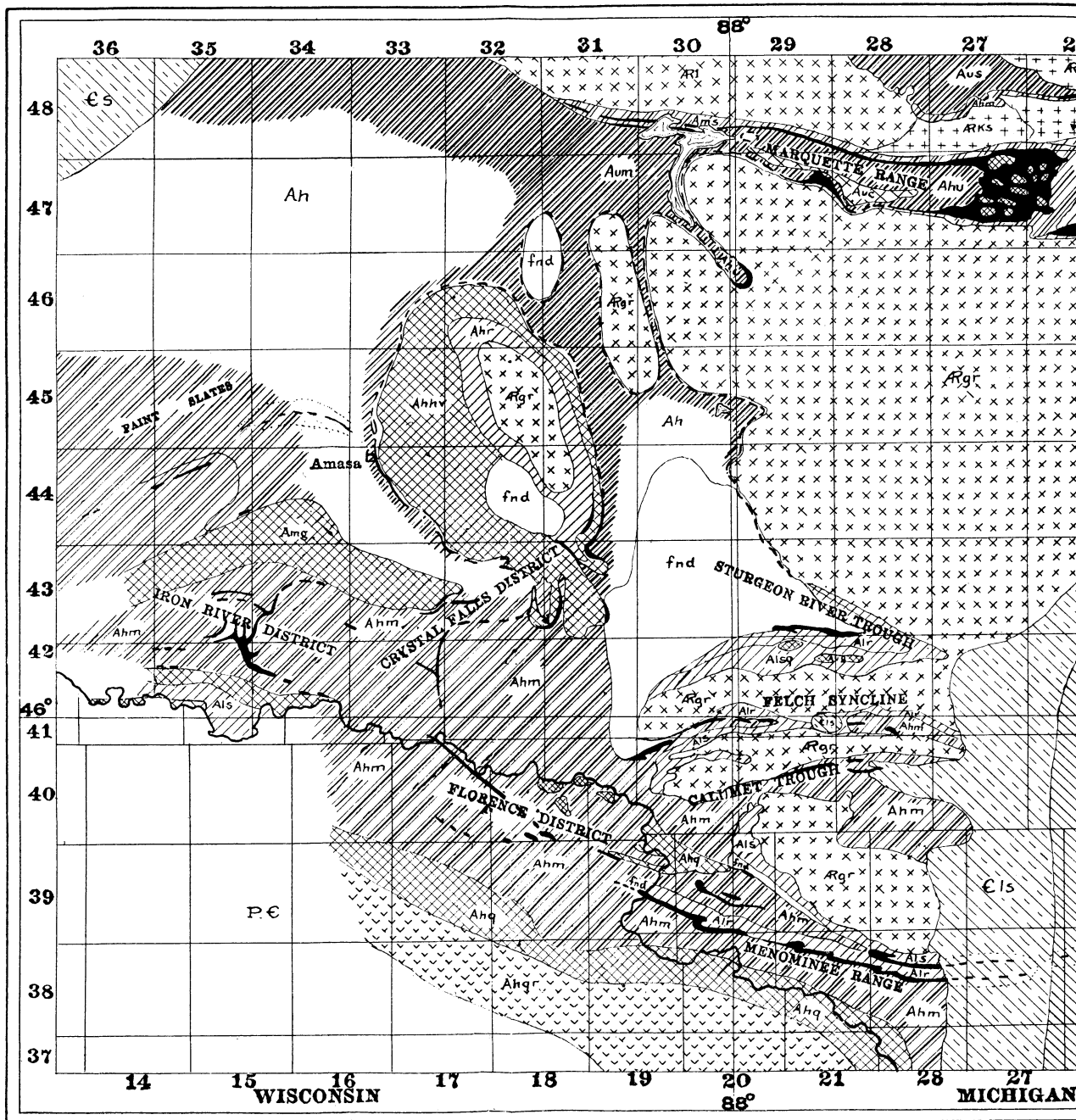
through the Red Rock mine and southward, the iron formation is correlated with the Vulcan or Upper Huronian notwithstanding the facts (1) of similar position with reference to the underlying Hemlock volcanics, (2) that the strike of the magnetic line north of the Red Rock mine indicates a continuity of the Vulcan iron formation there with the Negaunee a little farther north, and (3) that there is no evidence whatever beyond some difference in degree of metamorphism to show that the iron formations in section 27, T. 46 N., R. 33 W., and at the Red Rock mine are not one and the same.

The reason why the iron-bearing series (Vulcan) of the Crystal Falls-Iron River-Florence district was not correlated with the Negaunee by the United States Geological Survey is a simple one. In the Menominee Range, Van Hise and Bayley found that the iron-bearing series is unconformably above a quartzite-dolomite succession similar to the Lower Huronian of the Marquette Range and, under the dual classification, therefore Upper Huronian. Since the Negaunee formation (prior to 1904) had been correlated with the *Lower* Huronian, the question arose as to the position of the iron-bearing series in the intervening districts. It was reasoned that (1) because the iron-bearing series of the Crystal Falls district was at that time inseparable from the great Upper Huronian slate area opening out south and west from the Marquette district, and (2) because the Hanbury slate of the iron-bearing series of the Menominee Range seems to have areal connections with the slates of the Florence-Crystal Falls district, therefore the iron-bearing series in the latter district must be considered Upper Huronian. This conclusion was preferred, notwithstanding the evidence of continuity of the Vulcan and Negaunee formations in the northern part of the Crystal Falls district, and, as we shall see, became a source of considerable difficulty in applying the dual classification to the facts of succession in the Felch Mountain and Florence districts.

Recent developments in the Hemlock and Michigan mines at Amasa have fortunately determined conclusively that the Vulcan iron formation there which had been correlated as Upper Huronian is in reality Negaunee or Middle Huronian. On the thirteenth

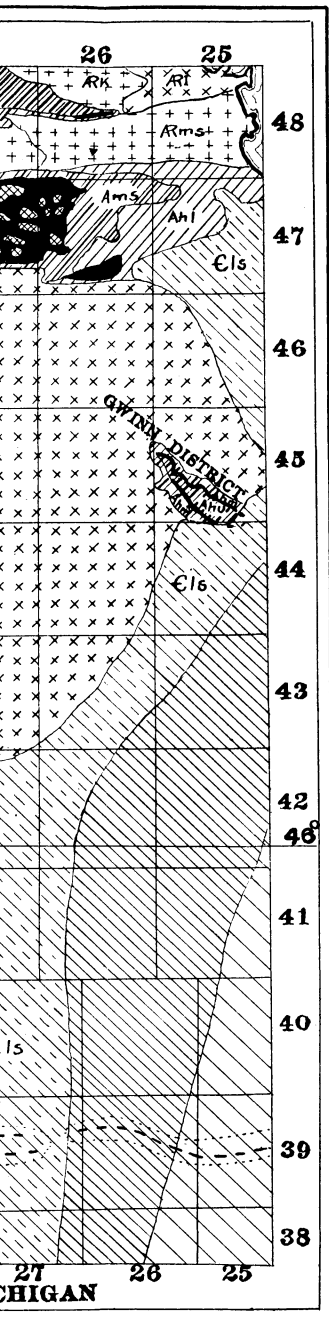
level of the Hemlock and Michigan mines the folds in the iron formation are truncated by a heavy conglomerate and quartzite carrying fragments of the Negaunee formation of all sizes up to several feet in diameter, including small, angular, hard jasper fragments, rounded pebbles of chert and ore, and great boulders of the iron formation. It is reported that this same conglomerate was found by drilling in similar relations to the iron formation about three miles south of Amasa and in section 36, T. 44 N., R. 33 W., about four miles farther southward. There can be no reasonable doubt that this conglomerate-quartzite is the Goodrich formation of the Marquette Range, where exactly similar relations are observed.

The productive iron formation at the Hemlock mine extends with only a few unexplored breaks in drift-covered country south-eastward around the great anticline of Hemlock volcanics and other rocks and is believed to be almost if not quite continuous with the iron formation passing through the Hollister, Armenia, and other mines in the vicinity of Crystal Falls. Such continuity is indicated, so far as definite information is available, by drilling, underground openings, and magnetic surveys. Furthermore, the iron formation on the west and southwest sides of the great Crystal Falls oval anticline maintains the same position with reference to the underlying Hemlock volcanics that it does on the north and east sides. Therefore if the iron formation at the Red Rock and Hemlock mines is Negaunee, the burden of proof rests on those who would assert in the absence of any supporting facts that the Upper-Middle Huronian unconformity cuts out the Negaunee iron formation and occupies an inferior position with reference to the Vulcan iron formation at any or all points southward. This practical continuity was accepted by Clements in 1899 and by Leith and Van Hise in 1911, as shown on the maps issued in *Monographs* 36 and 52 of the United States Geological Survey. In fact, Leith and Van Hise argue in this work that the iron formation at the Hemlock mine is *not* Negaunee *on the assumption of practical continuity with the Vulcan formation of the Crystal Falls district to the south and lack of continuity with the Negaunee formation a few miles northward.*



GEOLOGIC MAP OF PARTS OF MICHIGAN AND WISCONSIN

FIG. 3



## LEGEND

### PALEOZOIC

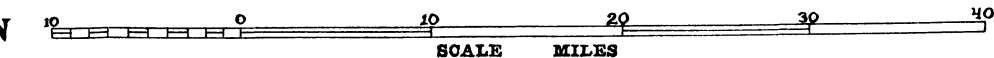
Ordovician	Middle		Limestones and dolomites
	Lower		White sandstones
Cambrian	Upper		Lake Superior sandstone

### PROTEROZOIC (Algonkian)

Huronian Series	Upper		Aug - Greenstones Auc - Clarksburg Formation (Basic Intrusives Acid Eruptives)
			Aum - Michigamme slates Aus - Ferruginous slates (Quartzites and slates including Iron Bearing Formations)
			Ahgr - Intrusive Granites
	Middle		Ahhv - Hemlock Volcanics Amg - Greenstones Ahq - Quinnesec Schists
			Ams - Siamco slates Amp - Paint slates Ahm - Middle Huronian slate (Quartzites and slates including Iron Bearing Formations)
			Als - Saunders Formation Alr, Ahr - Randville Dolomite (Quartzites, Dolomites, Slates)
	Lower		Als - Saunders Formation
			Alr, Ahr - Randville Dolomite
			(Quartzites, Dolomites, Slates)

### ARCHEOZOIC

Archean	Laurentian		Argr - Granite (Granites and Gneisses)
	Keewatin		Arms - Mona Schists Arks - Kitchi Schists (Green Schists and Iron Bearing Formations)
			Undifferentiated Pre Cambrian
			Undifferentiated Huronian
			Formation not determinable
			Iron Bearing Formation
			Magnetic Lines



CORRELATION OF THE NEGAUNEE (IRON-BEARING) SERIES WITH THE  
VULCAN (IRON-BEARING) SERIES OF THE STURGEON TROUGH,  
FELCH MOUNTAIN DISTRICT, CALUMET TROUGH, AND MENOM-  
INEE RANGE

These ranges lie south of the Marquette district and east of the Iron River-Crystal Falls-Florence district and form eastward-projecting tongues of the Huronian of this great area (see Fig. 3).

1. *Sturgeon River syncline*.—The Negaunee formation has been traced by outcrops, exploration, and magnetic surveys from the Marquette Range into the north limb of the Sturgeon River syncline. From near Witch Lake, about 8 miles south of Republic, the Negaunee formation is shown by the mapping of the United States Geological Survey to rest directly on the Archean. In the Sturgeon syncline, however, the Archean is overlain by the Randville dolomite and Sturgeon quartzite, equivalent to the Kona and Mesnard of the Lower Huronian in the Marquette Range. On the south limb of this syncline the iron formation reappears above the Randville dolomite and has naturally been correlated with the Negaunee of the north limb.

2. *Felch Mountain district*.—The Felch Mountain district is a narrow syncline of Huronian rocks downfolded in the Archean, from one to two miles wide, trending east-west, and, like the Sturgeon trough, opening out westward into the great slate area of the Crystal Falls district, wherein the structure is obscured. It is separated from the Sturgeon trough north of it by an anticline on which the Archean appears as a belt of granite about  $2\frac{1}{2}$  to 3 miles wide. In the Felch syncline there is an iron formation (Groveland) similar to that in the Sturgeon trough, separated from the quartzite-dolomite below by conformably underlying sedimentary schist (Felch schist) which has not been observed in the Sturgeon trough, although it may be present there also. Bayley makes no mention of the Negaunee formation of the Sturgeon trough in 1899,<sup>1</sup> although it was subsequently discovered through exploration and is shown on the maps of the United States Geological Survey published in 1911.<sup>2</sup> On these maps the iron formation in the Sturgeon trough is called Negaunee (Middle Huronian) and in the Felch syncline

<sup>1</sup> *Monograph 36, U.S. Geol. Survey.*

<sup>2</sup> *Monograph 52.*

Vulcan (Upper Huronian). This seems to be an arbitrary classification and represents the necessity of making the change somewhere from the Negaunee of the Sturgeon trough to the Vulcan of the Menominee Range. Lithologic similarity, proximity, and, so far as known, similarity of succession were cast aside in favor of the supposition that the Felch schist opens out and connects with sediments to the west which had been correlated as Upper Huronian, although the area in which the connection is indicated is deeply drift-covered and devoid of rock exposures. But even if this connection were a fact, as it may be, it constitutes in our opinion merely an added reason why the Groveland iron formation should be correlated with the Negaunee, since the Crystal Falls slate-iron formation series has been shown to be more probably *Middle* rather than Upper Huronian.

As a matter of fact Smyth *did* correlate the Groveland with the Negaunee formation in 1899, but after Seaman's discovery of the unconformity at the base of the Ajibik quartzite necessitated the correlation of the Negaunee series with the *Middle* Huronian (1904), Van Hise and Leith in 1911 took the Groveland out of the *Lower* Huronian and placed it in the *Upper* Huronian. In order to make this change it was necessary to assign a highly metamorphic quartzite-mica schist series which is unconformably *above* the Groveland to the Keweenaw or Paleozoic, for the reason that no place was then left for it in the Huronian group. Smyth was obviously right in correlating the Groveland with the Negaunee formation. The quartzite-mica schist series above the Groveland bears no resemblance to the Keweenaw or Paleozoic. It is Huronian, and we believe it should be correlated with the Copps, part of the Michigamme<sup>1</sup> and the Princeton series. The quartzite which is unconformably above the slate-iron formation series (Animikie) of the Florence district is similarly correlated.

3. *Calumet trough*.—In the Calumet trough, about 4 miles south of the Felch syncline, the situation is practically identical with that in the Felch Mountain district, and the same arguments for revision of the correlation apply here as in the Felch district. In other words, the iron formation now assigned to the Upper

<sup>1</sup> For division of the Michigamme series, see discussion below.

Huronian is believed to be really an equivalent to the Negaunee of the Middle Huronian. Rocks similar to the quartzite-mica schist series of the Felch syncline are exposed at the old Hancock exploration in T. 41 N., R. 27 W., and in at least one or two places near the southern edge of the Calumet trough. Each of the three Huronian series seems to be represented here exactly as in the Felch syncline a few miles north.

4. *Menominee Range*.—The general similarity of the iron-bearing series of the Menominee district with that in the Sturgeon, Felch, and Calumet troughs and in turn with certain phases of the Negaunee formation of the Marquette district, its similarity in relation to the underlying Lower Huronian, and its areal connections with the great slate-iron formation series of the Florence-Crystal Falls district determine that the Vulcan of the Menominee Range is probably of Negaunee age, and that if the iron formation in the districts intermediate between the Menominee and the Marquette ranges is Negaunee there is no basis on lithological, structural, or other grounds for assigning the iron formation of the Menominee Range to any horizon other than Negaunee, i.e., Middle Huronian.

Leith has described a remnant of cherty quartzite, of a maximum thickness of 70 feet, lying apparently unconformably between the Randville dolomite below and the Traders member of the Upper Menominee series above in the vicinity of Norway,<sup>1</sup> but he places no emphasis on it so far as concerns its significance in the correlations. This formation, according to the more recent opinion of Dr. Leith,<sup>2</sup> is a remnant of regolith unremoved by erosion in Lower-Middle Huronian time.

CORRELATION OF THE IRONWOOD SERIES (ANIMIKIE) OF THE  
GOGEBIC RANGE WITH THE VULCAN (MIDDLE HURONIAN)  
SERIES OF THE CRYSTAL FALLS-IRON RIVER-FLORENCE-  
MENOMINEE DISTRICT ON THE BASIS OF SIMILAR RELATIONS  
TO INTRUSIVE GRANITE

*Area southeast of the Gogebic Range including Marenisco, Turtle, Manitowish, Vieux Desert, Conover, Iron River, Crystal Falls, and Menominee districts*.—Probably the most striking feature of the

<sup>1</sup> *Monograph 52, U.S. Geol. Survey*, pp. 234-35.

<sup>2</sup> As expressed in conversation with the writer.

Middle Huronian (Animikie) of these districts is the general prevalence of intrusive granite. Heretofore these granites have been variously correlated, from Laurentian in the Gogebic, northern Wisconsin, and Menominee districts through the Upper Huronian in the Crystal Falls district to Keweenawan in the Florence-Menominee and northeastern Wisconsin areas.

In the Menominee district Bayley found that the granite south of the Menominee River intrudes a series of basic volcanics called the Quinnesec schist, which he correlated with the Keewatin. Although it was realized that the correlation of the Quinnesec schist as Keewatin introduced a conception of structure quite out of accord with natural inferences on the basis of the facts, it remained for Corey and Bowen, working under the direction of Van Hise and Leith in 1905,<sup>1</sup> and Hotchkiss in 1910,<sup>2</sup> to show conclusively that the Quinnesec schist is partly intrusive into, but in greater part interbedded with, the upper part of the Upper Huronian, i.e., Animikie.<sup>3</sup>

Inasmuch as the granite was thus proven to be the youngest rock in these districts, and the youngest pre-Cambrian sediments had been correlated with the *Upper* Huronian, Leith and Van Hise in 1911<sup>4</sup> correlated the granite with the Keweenawan and extended the boundaries south and east to include several thousand square miles of acid intrusives in north-central Wisconsin which had been mapped and described by Weidman in 1905.<sup>5</sup>

It is interesting to note here that Brooks and Wright had correctly interpreted these relations as early as 1876, although they did not, at that time at least, comprehend the extent of the great mass of intrusive granite. To quote from Brooks:

In the summer of 1874 Chas. E. Wright and myself, exploring the country west and south of the Menominee River about 90 miles from its mouth, under the auspices of the Wisconsin Geological Survey, observed a large granite

<sup>1</sup> Unpublished notes of field work done in 1905 by G. W. Corey and C. F. Bowen.

<sup>2</sup> Unpublished field notes of W. O. Hotchkiss.

<sup>3</sup> Middle Huronian of this article.

<sup>4</sup> *Monograph* 52, *U.S. Geol. Survey*.

<sup>5</sup> S. Weidman, "The Geology of North Central Wisconsin," *Bull. Wis. Geol. and Nat. Hist. Survey*, No. 16, 1907.

area, the north edge of which was bounded by dark colored hornblendic and micaceous schists of Huronian age, which I have since concluded are equivalents of the youngest member of that series yet observed in the Marquette iron region. . . . The lithologic character of this wide granite belt bore so much resemblance to the Laurentian rocks, which are extensively developed on the waters of the Sturgeon River in Michigan, 10 to 20 miles to the northeast, that we were disposed at the time to believe that some phenomena of folding or faulting had brought rocks belonging to that system to the surface in an unexpected quarter. Professor Pumpelly and myself, several years previously, had observed, farther to the north and west, similar granitic rocks crossing the Michigamme and Paint rivers (branches of the Menominee), presenting similar puzzling relations with beds known to be Huronian, and younger than as well as lithologically different from any rock then known to be of that period.

A careful consideration of all of the facts to be observed in the Menominee region confirms me in this hypothesis. . . .<sup>1</sup>

The conclusion of Brooks is confirmed by the work of Hotchkiss in the Florence district of Wisconsin in 1910.<sup>2</sup>

In 1911-14 the writer and assistants, through field mapping and diamond drilling, traced what appears to be this same granite from the Iron River district westward through the Animikie series of the Vieux Desert-Conover district and Manitowish, Turtle, and Marenisco ranges, in all of which it is in intrusive relation with the sediments, and connected it with the "Eastern Laurentian area" of Van Hise and Irving on the eastern Gogebic Range, which was considered by these geologists to form a part of the Archean basement complex, whereas it actually intrudes the Lower and Middle Huronian series and is unconformably overlain only by the Upper Huronian (Copps) series. *Thus the great granite batholith of northern Wisconsin has been fairly demonstrated to be, not only in intrusive relations with the Animikie sediments over several thousands of square miles, but also to be overlain unconformably by a pre-Cambrian series which is unconformably below the Keweenaw.*

Inasmuch as the Vulcan (Animikie) series of the Crystal Falls, Iron River, Menominee, Florence, and other Michigan districts has been shown to be very probably equivalent to the Negaunee

<sup>1</sup> T. B. Brooks, "On the Youngest Huronian Rocks South of Lake Superior and the Age of the Copper Bearing Series," *Am. Jour. Sci.*, Vol. II (1876), 206-7.

<sup>2</sup> Unpublished manuscript.

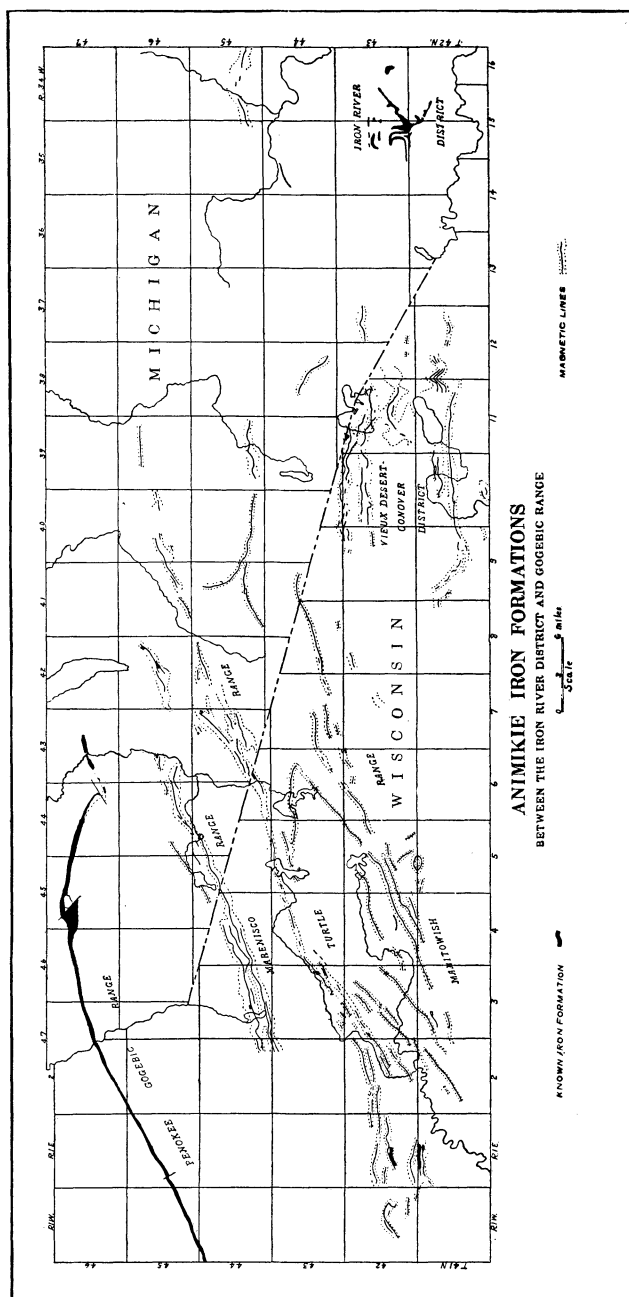


FIG. 4

series of the Marquette Range and the Ironwood series of the Gogebic Range, the age of this great granite batholith and its outliers may be considered as late Middle Huronian.

CONSIDERATION OF ARGUMENTS WHICH MAY BE ADVANCED FOR  
THE RETENTION OF THE CORRELATION OF THE ANIMIKIE AS  
UPPER HURONIAN

We have seen that the correlation of the Animikie as Upper Huronian dates from the earliest work of the United States Geological Survey in the Lake Superior region. It seems reasonable to believe that if the early workers in the Gogebic and Marquette ranges had recognized that the Huronian of both exhibits a *tripartite* rather than a dual division, the Animikie would have been considered by them as Middle Huronian rather than Upper Huronian. We have referred to some of the difficulties which were encountered in the application of the dual classification to some of the other Michigan ranges and have shown how these difficulties largely disappear in the correlation of the Animikie series as Middle Huronian. Having established the basis of the proposed correlation, we may turn to a consideration of some of the objections which may be offered to it.

Dr. Leith has emphasized the general similarity of the slate in the great Iron River-Crystal Falls area and the Animikie slates of the Cuyuna and Mesabi districts of Minnesota, and believes that "there is probably but one great slate formation of *this type* in the Lake Superior region." Although this observation has little bearing on the question of whether the Animikie is Middle or is Upper Huronian, it may be observed that this similarity is marked so far as concerns the slates which occur in areal association with the iron formation, but does not extend to the great mass of slate which occupies a large area of indefinite boundaries north and west of the Crystal Falls-Iron River iron-bearing area. These rocks are mainly graywacke of uniform composition and appearance and are not at all similar to the fine-grained gray and black pelites of the Animikie series which are associated with the iron formation (Vulcan) in the Iron River, Crystal Falls, Florence, and Menominee districts and the Negaunee iron formation of the Marquette Range.

The contrast is so marked that in 1910 I described these graywackes under the distinct formation name<sup>1</sup> of Paint slate and called attention to the structural evidence indicating that they are stratigraphically *above* the Vulcan (Animikie) series.

The correlation of the Paint formation presents a difficult problem. It constitutes a large part of the Michigamme series heretofore correlated with the Upper Huronian. We have seen that there is strong evidence that the Vulcan slate-iron formation series of the Iron River-Crystal Falls district, which has been described as a part of the Michigamme, is Middle Huronian. That part of the Michigamme slate which is *known* to be Upper Huronian is confined to a limited area adjacent to the western part of the Marquette iron range and the northern part of the Crystal Falls district where it is plainly unconformably above the Negaunee iron-bearing series. If the Paint slate is *conformable* with the Negaunee-Vulcan, it follows that the part of the Michigamme slate which is Upper Huronian must rest unconformably on it, and from the areal distribution of these formations it appears that the plane of the unconformity should intersect the erosion surface somewhere *north* of the Paint formation north of the Iron River district. Unfortunately, a general scarcity of exposures in the area where the unconformity may be expected to occur and the difficulty of identifying horizons over any considerable distance in formations of these kinds will render the discovery and mapping of this unconformity, if it exists, difficult. It is being searched for at the present time.

As bearing on the probable age of the Paint formation it may be said here that the Wolf Lake granite, north of Watersmeet in T. 46 N., R. 39 W., is intrusive in quartz-mica schist which, judging from lithology and areal relationships, is a metamorphic equivalent of the Paint slate. The Wolf Lake granite is correlated with the Presque Isle granite of the Gogebic Range and that in the intervening territory and is believed to be an outlier of the great granite batholith of northern Wisconsin. The Presque Isle granite intrudes the *Middle* Huronian (Animikie) and yields detritus to the Upper

<sup>1</sup> R. C. Allen, "The Iron River Iron Bearing District of Michigan," *Publ.* 3, *Mich. Geol. and Biol. Survey*, 1910.

Huronian. If the Presque Isle and Wolf Lake granites are of the same age, it follows that the Paint formation is Middle Huronian.<sup>1</sup>

In the argument for retention of present correlations which follows, Dr. Leith is unable to accept the correlation of the Vulcan series of the Crystal Falls-Iron River district with the Negaunee series of the Marquette Range, for the reason, among others, that the Vulcan iron formation occurs in lenses in slate, as against the well-defined position of the Negaunee formation in the stratigraphic succession. In this connection it should be observed that this dissimilarity of occurrence is fully as great and of the same order in comparison with the Animikie series of the Gogebic, Mesabi, and old Menominee ranges with which the Vulcan is correlated by him as well as by me. If the observation is of importance in the one case, is it not equally so in the others?

In further reference to the correlation of the Negaunee and Vulcan iron-bearing series, it may be observed that the Negaunee series in the Marquette trough is thick and well developed and should be expected to occur in the down folds over a large area. The Ajibik quartzite has a maximum thickness of 700-750 feet, the Siamo slate probably from 500-600 feet, and the Negaunee iron formation in excess of 1,000 feet. The Siamo slate is not persistent on the south side of the trough west of the latitude of Ishpeming, where the Negaunee rests directly on the Ajibik quartzite. The Negaunee formation, as well as the underlying quartzite, becomes thinner in this direction, and in the Sturgeon trough and around the great anticline in the Crystal Falls district the Ajibik formation, according to the latest maps of the United States Geological Survey (1911), is entirely absent, the Negaunee formation there resting directly on the Lower Huronian. The correlation of the Vulcan formation of the Crystal Falls district with the Negaunee formation of the Marquette district is criticized by Dr. Leith on the basis of the apparent absence of the Ajibik quartzite in the former area. However, *the Ajibik formation is known to have disappeared from beneath the Negaunee in the direction of the Crystal*

<sup>1</sup> R. C. Allen and L. P. Barrett, "Contributions to the Pre-Cambrian Geology of Michigan and Northern Wisconsin," *Publ. 18, Mich. Geol. and Biol. Survey* (in press).

*Falls district*, as indicated on the latest maps of this district published by the United States Geological Survey.

As to the importance which may be attached to the absence, in the southern part of the Crystal Falls district, of the formations which underlie the Ajibik quartzite adjacent to the iron formation in the Marquette Range, it may be observed that these formations appear not only on the great anticline in the northern part of the Crystal Falls district but on the upturned limbs of the synclines to the east—the “eastward-projecting tongues of this great area,” wherein erosion has cut down into the Archean.

Finally, it may be said that it is easier to account for the disappearance of a coarse clastic basal member which is obviously related to a shore phase of deposition than to justify, in the absence of definite supporting facts, the assumption of a rather abrupt disappearance of an entire series.

It may be objected further to the correlation of the Vulcan and Negaunee formations that the hard ore horizon of the upper part of the Negaunee is not duplicated in the Vulcan of the Crystal Falls district. This fact has little bearing on the correlation because this phase of the Negaunee is related, as shown by Van Hise and others, to a controlling structural condition which nowhere occurs in the Crystal Falls district, i.e., it is the result of deformational-metamorphic alteration adjacent to the heavy competent Goodrich quartzite-conglomerate. This relationship, areally considered, is entirely fortuitous and may be expected to appear only where the structural conditions and deformation on which it is dependent are in evidence. So far as *lithology* is concerned the Vulcan and Negaunee formations are in other respects practically identical.

Dr. Leith opens his discussion of the Upper-Middle Huronian unconformity at the Hemlock mine and vicinity as follows: “Practically no new evidence has been brought in, in the crucial area between the Marquette and Crystal Falls districts, and such additional evidence as there is, is damaging to the conception of the new hypothesis.” The discovery of that unconformity has apparently reversed Dr. Leith’s ideas concerning the correlation of the iron formation in the northern part of the Crystal Falls district which he recently (1911) correlated with the Vulcan but

now correlates with the Negaunee and refers to it as "distinctively Negaunee type." If the Hemlock iron formation and the Vulcan were considered the same in 1911 and prior years, what *new evidence* may be cited on which they may be separated *now*? The only *new evidence* is the discovery of the fact that the iron formation at the Hemlock mine and for several miles north and south of it is Negaunee, and this is therefore precisely the evidence to which Dr. Leith refers as damaging to the new hypothesis and in confirmation of the old correlation.

Dr. Leith has also laid emphasis on the fact that the unconformity at the Hemlock mine has not been traced across the northern part of the Iron River district and therefore that proof is lacking that any part of the Michigamme slate occupies an inferior position with reference to this unconformity. This is a weakness in the new hypothesis, but it is certainly not greater than the weakness in the argument which has been advanced that this unconformity cuts out the Negaunee formation in the northern part of the Crystal Falls district and in some unknown place passes beneath the Vulcan formation of the southern part of the district. If the greenstone belt north of the Iron River district is Hemlock (Middle Huronian) as correlated by Clements as well as by Van Hise and Leith (1911), there is an anticlinal structure here which *demands* that the unconformity turn "back on itself at some place south of Amasa" and carry "out westward to the north of the Iron River-Crystal Falls district" (see Fig. 3). This would seem a necessary consequence of Dr. Leith's published interpretation of the structure with which I agree (in reversal of my opinion in 1909) because of the discovery of the unconformity in question and the evidence based on the recent drilling in the vicinity of Crystal Falls. In brief, the structural facts point to a closely compressed syncline between the two masses of volcanics, similar to those northeastward including the Republic trough, with the formations involved sharply upturned on its opposite limbs.

#### GENERAL REMARKS ON THE CORRELATION OF THE ANIMIKIE SERIES WITH THE MIDDLE HURONIAN

The correlation of the Animikie series with the Middle Huronian eliminates what would otherwise be the necessity of assuming a

*fourth* Huronian series of which the Copps formation of the Gogebic Range would be the sole representative. The practical identity of the Huronian succession of the Gogebic and Marquette ranges, together with the marked similarity of the Copps formation and the Upper Huronian of the Marquette and Gwinn districts, is believed to be an adequate basis for moving the Animikie of the Michigan and other Huronian districts downward into the Middle Huronian, particularly as this correlation, as we have seen, eliminates what would otherwise be a further necessity of including the uppermost series of metamorphic sediments in the Felch, Calumet, and Florence districts in the Keweenawan or the Paleozoic, where they obviously do not belong.

The anomalous position in the correlations of the great Negaunee iron-bearing series has been unsatisfactory to many students of the pre-Cambrian for many years.<sup>1</sup> We now have a firm basis for the correlation of the Negaunee series with the great productive iron-bearing series of the Animikie of all of the other districts of the Lake Superior region and are able to recognize the consideration that the unique conditions which resulted in the deposition of the great Huronian iron formations were regional rather than local and should be correlated in time. While it is true that the names now used have come to have well-understood significance because of long usage, it cannot be held that this is a valid argument for the retention of a classification which no longer fairly interprets the facts of present knowledge.

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#### ARGUMENTS FOR RETAINING THE PRESENT CORRELATION

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C. K. LEITH

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Doubts as to the present correlation of the Michigan formations center in the great slate area (Michigamme slate) carrying the iron formation of the Iron River, Crystal Falls, Florence, and con-

<sup>1</sup> See A. C. Lane and A. E. Seaman, *Mich. Geol. Survey, Annual Report*, 1908, pp. 23-30. In presenting their mature conclusions on Michigan pre-Cambrian successions, Lane and Seamen correlate the Animikie iron-bearing series throughout with Negaunee (Middle Huronian) of the Marquette Range.

tiguous districts, which lies between the well-determined succession of the Gogebic on the one hand and the well-determined succession of the Marquette on the other. The close folding of this area, its intrusion by granite, its relatively soft character, causing low relief and few exposures, the fact that exploration and development in this area are much less advanced than in the Gogebic and Marquette districts, the fact that there is a general absence of distinctive quartzite or other formations as horizon-markers, have made it difficult to carry correlations with certainty through this great slate area. In general, the slates show evidence of shallow water or delta deposition in their rapidly alternating bedding, current bedding, ripple marks, graphitic layers, and considerable thickness. In all these respects it differs from any of the slates, other than Animikie, in the pre-Cambrian of Lake Superior. It is substantially like the slate above the Animikie iron formation of the Gogebic and Mesabi districts, like the Animikie of the Cuyuna and St. Louis River districts, and like the Michigamme slate of the Upper Marquette series (Animikie). Throughout the great slate areas of this type in the Lake Superior region the iron formation has somewhat similar characteristics, being in irregular folded, more or less discontinuous, lens-like bands within the slates, without definitely determinable horizon. The occurrence and nature of the ores are so much alike throughout these great slate areas that they are naturally grouped by the explorers or mining men.

Nearly all investigators of the geology have noted these broad similarities and have correlated the slates of these districts as Animikie.

In arguing for the revision of pre-Cambrian correlation of Michigan, Allen accepts the correlation of the slate series of the Iron River-Crystal Falls district with the Animikie or Upper Huronian of the Gogebic district, but its correlation with the Upper Huronian or Animikie of the Marquette district is disputed on the ground that it may be the equivalent to the Middle Huronian of the Marquette district, leaving the Upper Huronian of the Marquette district available for correlation with the newly discovered Copps series. The discovery of this new series leads, naturally, to a search for a more extensive occurrence in the region, but, in my

judgment, the proposed change runs squarely across certain fundamental facts which will not give way to the new hypothesis, however attractive it may be. Allen's argument is based (1) on the supposed equivalence of the Iron River slates (and iron formation) with the Animikie in the Gogebic district, (2) on the supposed equivalence of the Iron River slates with the Middle Huronian of the Marquette district.

1. That the slates and iron formation of the Iron River district are to be correlated with the Animikie of the Gogebic district is the conclusion that has been reached by nearly all investigators, and in the absence of definite proof to the contrary must stand. I would suggest, however, that the recent discovery of the Copps series opens up an alternative, that the Iron River series is equivalent to the new Copps series and both equivalent to the Upper Huronian of the Marquette district. This would have the effect of throwing the Animikie down a step in the scale, but would not disturb the local correlation between the Marquette and Crystal Falls-Iron River districts. This is only a possibility, for outcrops are few in the connecting areas, metamorphism due to intrusion has been intense, and I see no likelihood for some years of sufficient information being available to develop the evidence necessary for this possible conclusion.

2. That the slates and iron formation of the Iron River-Crystal Falls district are equivalent to the Negaunee (Middle Huronian) of the Marquette district is a possibility which has been often considered discarded. Practically no new evidence has been brought up in the crucial area between the Iron River-Crystal Falls district and the Marquette district, and such additional evidence as there is, is damaging to the conception of the new hypothesis.

The great essential fact of the situation, which cannot be ignored, is that in the Marquette district the Negaunee iron formation (Middle Huronian) is unconformably below a great slate series (Michigamme slates, Upper Huronian) which contains lenses of iron formation identically like those in the Crystal Falls and Iron River districts, and contrasting with the Negaunee iron formation of the Negaunee. The Michigamme slate of the Marquette district is all but proved to be the same as that in the Iron River and Crystal

Falls region. They are areally contiguous, contain the same lithologic types, and throughout contain iron formation of remarkably uniform type and occurrence. To assume that they are not of the same age requires not only the introduction of an entirely hypothetical unconformity, but also the assumption that the Negaunee formation has entirely changed its character to the exact extent necessary to make it similar to the slate-iron formation of the Crystal Falls-Iron River district. Such a thing is of course possible, but extremely improbable.

Nowhere in the Crystal Falls-Iron River district has the close folding and erosion disclosed the distinctive Siamo slates of the underlying Ajibik quartzite characteristic of the horizons below the Negaunee. Neither has it disclosed any formations underlying the Ajibik close at hand, with the exception of certain volcanics. Somewhere they should appear on the erosion surface if the series were really Middle Huronian.

That there are two slates in the Iron River-Crystal Falls district, as argued by Allen, is possible, but no trace whatever of an unconformity has been found, and the differences in lithology which he cites as evidence are completely duplicated by differences in lithology in the Upper Huronian slates of the Marquette district.

The principal argument for a change in correlation is based on a supposed direct areal connection of the Negaunee iron formation of the Marquette district with the iron formation of the Iron River-Crystal Falls district. With some interruption, due to folding, the Negaunee iron formation has been traced southwestward from the Marquette district to a point in the northeast portion of the Crystal Falls district near Amasa, on the west side of an area of underlying Hemlock volcanics. Somewhere south of this area the character of the iron formation changes, for before reaching the iron formation belts in the slates (Upper Huronian) in the vicinity of Crystal Falls, the formation is of different character, the underlying fragmental phases are absent, and both walls are conformable slate. The difficulty of drawing a line here, in the absence of exposures and complete exploration, has long been obvious, and yet the contrast in types and occurrence of iron formation seem to require that some line be drawn. In successive maps the line has shifted more or less.

The general accuracy of the conclusion that the two formations are of different age has been strengthened by the finding of a basal conglomerate resting directly on the Negaunee formation and locally cutting it out in the general vicinity of Amasa. So far as this conglomerate has been traced (6 or 8 miles) it shows conclusively that the slate series on the west is unconformably above the Negaunee formation on the east. Where this unconformity goes to the south is not yet discovered, and hence there is still doubt as to the exact location of the line of contact between the Negaunee iron formation and the Upper Huronian. The extension of the unconformity along its trend south or southeast in general separates the formation of distinctly Negaunee type on the east from the formation of distinctly Iron River-Crystal Falls type associated with slates on the west. Allen, on the other hand, would turn the unconformity back on itself at some place south of Amasa and carry it out westward to the north of the Iron River-Crystal Falls district, in order to leave the Iron River-Crystal Falls iron formation with the Negaunee formation below the unconformity. It seems possible that the unconformity to the south of Amasa cuts out the Negaunee formation, allowing the Upper or Animikie series to lap over against the underlying formation, exactly as happens in places in the Marquette district. The statement that the known Negaunee formation is areally connected with the known Crystal Falls-Iron River iron formation is based on general similarity of trend of the iron formation, as shown by explorations and various magnetic belts. As the two have been folded together, this similarity of trend is to be expected in any case. There is plenty of room for the unconformity to run diagonally across this general trend at almost any point. Exactly the same argument for connection in the Marquette district would result in mapping Negaunee iron formation with Upper Huronian iron formation, whereas the two are really separated by a profound unconformity.

The writer is not impressed with the argument that if a threefold division of the Huronian had been first made, subsequent correlation would have been of a different sort. It is entirely true that different correlations might result in starting from a twofold or threefold basis of division, but the history of correlation of pre-

Cambrian formations in the Lake Superior country discloses no backwardness in revising correlations as fast as facts are found to warrant revision. Seaman's discovery of a tripartite division in the Marquette district was immediately recognized by the geologists of the United States Geological Survey and was first published by C. K. Leith in 1904,<sup>1</sup> with permission of Professor Seaman. Neither may it be said that there is any delay in recognizing the significance of the supposed new formation in the eastern Gogebic district. In fact, the writer took some part in the field in the analysis of the situation leading up to this discovery. It may be freely conceded that in the past there was more emphasis on a given number of series as a basis of correlation, but the basis of correlation has been constantly widened by the addition of new criteria. It seems peculiarly inappropriate, therefore, to argue that what might have been done in the past on the basis of a preconceived notion of a number of series should serve as a primary basis of classification now when a much greater variety of facts is available.

In short, the suggested changes in correlation seem to the writer interesting possibilities, for which evidence must be carefully looked for in further geological work in this district, but that they are only possibilities and in the present state of knowledge cannot stand against the general considerations above outlined. It should not be overlooked that the new series suggesting these sweeping changes is yet known in but a few outcrops in a limited area where the folding and intrusion have been extensive, and that there is distinct possibility that the formation may have been of only local significance.

In case the newly proposed classification can be established it will be a welcome advance in our knowledge of Lake Superior geology. The purpose of this argument is not to discourage an attempt to make such an advance, but to indicate the difficulties inherent in the problem and the impossibility in the present state of knowledge of accepting an interesting hypothesis as a proved fact.

<sup>1</sup> C. K. Leith, *Trans. Am. Inst. Min. Engrs.*, Lake Superior meeting, 1904.